CICATS alternatively proposes that the FCC mandate the CICATS Reference Decoder that handles up to 1024 pixels horizontally and up to 512 lines vertically (without enhancement), is progressively scanned exclusively, has square pixel spacing exclusively, is a spatial and temporal base-layer technology, and supports frame rates of 24 Hz, 36 Hz, and 72 Hz (without enhancement).

CICATS alternatively proposes that the alternative immediately above be further modified only by substitution of three frame rates for the temporal base layer concept, the three rates being 24 Hz, 60 Hz, and 72 Hz. It is understood that by so doing conversions are required in the receiving sets, implying cost and quality penalties (but far less than those associated with the 18-format ACATS proposal).

CICATS further proposes that the FCC suggest, as recommended practice, how the CICATS spatial base layer might be enhanced to higher resolutions. These enhancements are not to be mandated at this time.

CICATS proposes that the FCC recommend that old analog content be used only on old analog channels, or else be converted at high quality at the transmission head-end to the new digital signal for use on the new digital TV channels.

Glossary

ACATS: Advisory Committee on Advanced Television Service, to the FCC.

Aspect ratio: The ratio of the width of a picture to its height. Standard (current) TV has an aspect ratio of 4:3 ("4 to 3") = 1.333. The ACATS proposal mixes 4:3 with 16:9 aspect ratios. 16:9 = 1.777 is a strange aspect ratio that is wider than current TV but is not a Hollywood compatible aspect ratio. Hollywood films are most often in 1.85 ("academy") aspect or in 2.37 ("scope") for very wide-screen films. Hollywood would apparently be content with a 2:1 aspect ratio, but not with 16:9.

Base Layer: See layering.

CICATS: Computer Industry Coalition on Advanced Television Service, representing 10 leading personal computer companies (hardware and software)

FCC: The Federal Communications Commission

Frame rate: The number of video pictures displayed per second. The goal is to seem continuous. Film's frame rate is 24 frames per second, where each frame is repeated 2 (or sometimes 3) times by a film projector to give the equivalent frame rate of 48 frames per second (or sometimes 72). The word "Hertz" is used often to abbreviate "frames per second". The highest ACATS frame rate is 60 Hz

[10] Underlined words refer to defined terms elsewhere in the Glossary.

("60 Hertz" or 60 frames per second), whereas computer consumers rejected 60 years ago in favor of 70 or more frames per second to avoid objectionable flicker. (Looking at a TV or PC screen out of one's peripheral vision reveals the flicker.) 72 Hz is an attractive frame rate because it is computer friendly and an easy multiple of film rate (film is a major source of all TV content).

Hertz (Hz): One Hertz is short for one cycle per second, or one frame per second. Frequencies were formerly expressed in cycles per second—for example, a radio station might broadcast at 98.1 on the radio dial, meaning at 98.1 megacycles per second. Today this would be expressed as 98.1 megaHz, in honor of electromagnetic pioneer Heinrich Hertz. In a related usage, the "width" of a TV channel is measured in Hz—6 megaHz per channel.

Interlace: Current analog TV scans each frame by first drawing every other horizontal scanline across the face of the TV set, then starting over at the top and drawing all the skipped in-between scanlines. The first set, called a "field", is said to be interlaced with the second set, or second field. Interlaced scanning is opposed to progressive scanning.

Layering: A layered system is a logical system of related frame sizes, rates, and resolutions (as opposed to a grab-bag of unrelated formats as in the ACATS proposal). A layered system has a "base layer" that must be honored plus "enhancement layers" that may be added to the base layer to make it higher resolution. A good example of a layering scheme is that used by Kodak's PhotoCD. Snapshots are taken to a photo house from which they are returned in digital form on a CD, Kodak's PhotoCD. Each of the snapshots will appear on the CD in several resolutions. The base resolution is 768x512 (approximately video resolution), but the CD also contains enhancement layers that are added to the base resolution to make it into 1536x1024 pixels or 3072x2048 pixels. So one CD contains at least these three resolutions. Similarly, a layered TV channel could contain several resolutions simultaneously so long as they were layered logically. ACATS misuses the term "layering" to simply mean a TV picture is layered atop a string of digital bits, which is layered atop a radio frequency modulation technique. Theirs is a much more generic use of the term than the CICATS (or Kodak) use.

Moore's Law: The "law" that says computers get twice as fast every 18 months. In general, anything digital gets twice as good every 1.5 years. For example, memory doubles or the processor gets twice as fast—for a fixed cost—every 1.5 years. To understand how stunningly fast this is, let's restate it as 10 times faster every 5 years (that's the same as 2 times faster every 1.5 years). During the 8 years that ACATS has been working on its proposal, personal computers have increased in speed and memory by a factor of 50 to 100 times (at the same cost). At the beginning of the ACATS process, PCs weren't powerful enough for TV, but now they are. There is good reason to believe that Moore's Law will continue to operate for another 15 years - thus for another

improvement of 1000 times over what we have today! This incredible digital revolution is what makes CICATS encourage the FCC not to freeze any digital standards now that it could better make 5-10 years from. We are simply incapable of predicting what an "order of magnitude" (10x) change means conceptually. Any standards made now will look foolish 5 years from now, so only the minimum should be done now. (Two years ago there was no Netscape, and Microsoft was not an Internet company. Things change *very* fast in the digital world. The old analog modes of thinking do not work.)

Order of Magnitude: One power of 10. So 100 is two orders of magnitude larger than 1. The term "order of magnitude" means more than simply a larger number, however. It implies a conceptual change as well. Moore's Law says that computers get faster by an order of magnitude every 5 years (at a fixed cost), but more importantly it also means that we require a different level of understanding every 5 years.

Pixel: Short for picture element. In the digital world, a picture is represented by an array of tiny samples or picture elements - so many per line and so many lines. (Pixels, by the way, are single points, not little squares or rectangles as popularly described. We are careful to say "square pixel spacing", not "square pixels".)

Progressive: Current PC screens draw each scanline in order from top to bottom. They are said to be "progressively scanned". This is opposed to interlaced scanning.

Reference Decoder: CICATS proposes a layered video format scheme by way of a reference decoder, which is a specification of the decoder of the new digital TV signal—separate from the display of that signal. This concept permits a degree of freedom not formerly present in these FCC-related discussions. For example, instead of specifying a specific horizontal resolution, which depends highly on the capabilities of a particular display, the CICATS Reference Decoder says only that the format must have 480 progressive lines (nominally) and square pixel spacing. So, if the display device has electronics and width enough to handle a 2:1 aspect ratio, then the Reference Decoder will honor a width of 960 pixels (assuming the industry has agreed to broadcast this signal). If the display device can only handle 4:3 aspect ratio (as the affordable ones today do), then the Reference Decoder would dictate a horizontal resolution of 640 pixels. The same decoder circuit, at the same parts cost, would handle either situation. The Reference Decoder is not hardware. It is a way of specifying a class of acceptable video formats rather than a single video format. Within this class there is no conversion required, but wide signals (wide aspect ratio) would have to be either letterboxed or pan-and-scanned to a display with smaller aspect ratio.

Resolution: The number of pixels per line and the number of lines - equivalently, the number of horizontal pixels and the number of vertical pixels.

Thus a resolution might be given as 2048x1024 pixels, meaning 1024 scanlines with 2048 pixels on each scanline - equivalently, a rectangular array of 2048 times 1024 pixels (about 2 million pixels). Standard (current) TV has 480 lines vertical resolution and about 700 horizontal. But it is interlaced, which brings down its effective vertical resolution to about 320 scanlines. The ACATS "high-definition" format of 1080 vertical lines is really about 700 lines since the 1080 lines are interlaced at the 60 Hz frame rate.

Spectrum: Simply all the channels used for TV, cable TV, AM radio, FM radio, ham radio, and so forth - treated as a single entity. The full electromagnetic spectrum is vast, including X rays, heat, and even ordinary light. The FCC has dominion over only the "radio frequency" – those uses listed in the first sentence of this paragraph. That is, the radio frequency spectrum is a subset of the full electromagnetic spectrum. One TV channel, whether old analog or new digital, is a slice of the radio frequency spectrum.

Square pixel spacing: This just means that the horizontal spacing between pixels is the same as the vertical spacing between pixels (or between scanlines). Although the conversion from non-square pixel spacing of many of the ACATS formats to square pixel spacing is straightforward, there are about 200 million PCs in existence that assume square pixel spacing and do not have the software for doing the conversion.

Exhibit C

Cost Comparison of ACATS and CICATS Set-top Converters, Receivers, and PC Decoders[1]

Introduction

Adoption of the ACATS standard portends a transition to digital TV (DTV) that will be enormously costly to consumers. In order for a consumer to receive any of the digital channels when these go on the air in 1998, or if the NTSC channels go dark at the ten-year mark as some propose, the only way for a consumer to use a legacy NTSC receiver to view DTV broadcasts will be to purchase a set-top converter box. These devices will not be inexpensive.

The cost of ACATS converters will be substantially greater than the cost of a converter that would be required under the CICATS proposal.

While the precise engineering and design specifications for DTV converters has not been established, it is possible to develop broad-guage estimates of the price levels that consumers can expect to confront at various stages of the migration period. An analogous product, already on the market, is a digital satellite service (DSS) television receiver, such as the DSS decoder.[2] This device receives a compressed digital signal from the satellite, decodes the signal and converts it into analog NTSC form suitable for display on a conventional NTSC receiver or monitor Hence, the current price of a DSS receiver provides a real-world starting point for our cost model.

The modulation scheme used by DSS is similar to that being proposed by ACATS, providing approximately 20 Mb/s per satellite transponder. Four or five MPEG-2 MP@ML SDTV streams are multiplexed together on one of these digital data channels.

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[1] This analysis was prepared for CICATS by Steve Gabriel, Architect, Graphics and Video Systems, Microsoft Corporation.

[2] DSS receivers are currently selling in stores at a retail price of approximately $500. However, if that retail price is in any way subsidized by the DSS provider or equipment manufacturer in order to encourage subscribership to the satellite service, the effective retail price of the unit would be considerably higher

The ACATS system can also do this in one of its modes of operation. Even though DSS brings only low-resolution, SDTV programming into the home, the multiplexing of the data brings the complexity of the demodulation and control section (front end) of the receiver to about that needed by an ACATS converter. The MPEG-2 decoder is also similar to that required by the ACATS standard, with one very important difference: An ACATS HDTV decoder needs to process data five times faster and uses five times more memory than is required for DSS. For complex processes, these requirements translate almost linearly to the cost of the devices involved. Hence, we assume that the full-function ACATS HDTV-capable MPEG-2 decoder section will cost approximately five times as much as the decoder used in a SDTV DSS receiver.

Description of the cost model

The cost model breaks the DSS receiver into three sections:

(1) Packaging and power supply hardware

(2) Demodulator and control circuits; and

(3) the MPEG-2 decoder.

The cost of the VLSI (Very Large Scale Integration) electronics that are employed in the digital converter units is expected to decrease steadily over the next 10 to 15 years, according to industry trends that are encompassed in a rule-of-thumb known as "Moore's law." Moore's Law states that the price of computation and memory halves every 18 to 24 months. Taking the more conservative end of this range, we assume here that costs will drop by 50% every 24 months

The first section — Packaging and power supply hardware — does not involve VLSI electronics and is thus not subject to Moore's Law. In our model, we assume that the cost of this section remains essentially constant over time. These costs are, of course, sensitive to overall production volume; hence, as demand (output) grows, small decreases in the packaging and power supply costs can be expected. Digital satellite receivers are already being manufactured in reasonable volume (2 million so far, another 4 million projected), so using present day prices for this section is not unreasonable.

Sections (2) and (3) — the Demodulator and control circuits and the MPEG-2 decoder — use VLSI electronics and will thus respond to Moore's law.

Structure of the cost model

The cost model contains the following variables:

PDSS	the present price of a DSS receiver
HW	the present fraction of the price of the DSS receiver that is not subject to Moore's law cost reductions, *e.g.*, case, power supply, circuit boards, etc.
VLSI	the remaining fraction that is subject to Moore's law, the VLSI electronics. HW plus VLSI add to one.
MPEG	the fraction of the VLSI electronics devoted to the MPEG-2 decoder
Half_life	Moore's law scaling factor, the number of years for price to drop in half

The CICATS base-line converter unit

Our prediction of the price of a DSS set-top converter is given by the formula

PDSS_future(t) = PDSS * [HW + VLSI * 2 ^ (-(T-1996)/Half_life)].

where T is the year. The exponent of 2 is the negative of the number of years into the future divided by the estimated half life of the price of the VLSI.

The CICATS base-line SDTV decoder is substantially equivalent in complexity to a DSS decoder, so the future price of a DSS receiver is a good predictor of the future price of a CICATS base-line SDTV decoder.

The ACATS set-top converter unit

To predict the price of an ACATS set-top converter, we use the formula:

PACATS(T) =
PDSS * [HW + VLSI * ((1-MPEG) + 5 * MPEG) * (2^(-(T-1996)/Half_life))]

Here we break the VLSI section into the non-MPEG part (which is essentially the same for both DSS and ACATS — the "1-MPEG" term) and the portion that is devoted to MPEG decoding, which is five times more expensive for full ACATS capability.

PC add-in converter/decoder cards

We can also estimate the prices of add-in cards for PCs, or of the electronics for the digital tuner and decoder of an ACATS HDTV set, by simply deleting the HW portion of the price. We assume that the *entire* collection of electronics responds to Moore's law. This very generous assumption probably underestimates the price.

Cost model results

For our model, we selected 15% as the fraction of the set-top box that does not respond to technology scaling. This may be low. For the fraction of VLSI devoted to MPEG, we used 50%. With a halving time of 2 years, this results in the following table comparing CICATS base-line converter costs to that for full ACATS-capable units. The first two price columns are the selling prices of set-top converters for existing NTSC sets. The next two columns are the incremental costs for a PC decoder card or the VLSI electronics inside the TV set.

Assumptions

HW	15%
MPEG	50%
1996 Price of DSS or CICATS	$500
Half life	2 years

Table 1

Cost Comparison of ACATS and CICATS
Set-top Converters, Receivers, and PC Decoders*

	Set-top Box		**TV Internals or PC Decoder**	
	CICATS	**ACATS**	**CICATS**	**ACATS**
1996	$500	$1,350	$425	$1,275
1997	$376	$977	$301	$902
1998	$288	$713	$213	$638
1999	$225	$526	$150	$451
2000	$181	$394	$106	$319
2001	$150	$300	$75	$225
2002	$128	$234	$53	$159
2003	$113	$188	$38	$113
2004	$102	$155	$27	$80
2005	$94	$131	$19	$56
2006	$88	$115	$13	$40
2007	$84	$103	$9	$28

* Prices shown are in constant 1996 dollars

ECONOMIC CONSIDERATIONS IN THE EVALUATION OF ALTERNATIVE DIGITAL TELEVISION PROPOSALS

Exhibit D
MM Docket No. 87-268

Lee L. Selwyn

prepared for the

Computer Industry Coalition on Advanced Television Service

July 11, 1996

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ECONOMIC CONSIDERATIONS IN THE EVALUATION OF ALTERNATIVE DIGITAL TELEVISION PROPOSALS

Lee L. Selwyn*

Introduction

There are an estimated 214-million NTSC television receivers and perhaps another 100-million NTSC VCRs currently in use in the United States.[1] New TVs are being added at an annual rate of about 25-million, while about half of that number are scrapped each year.[2] If the NTSC-based broadcasting standard is to be replaced by any of the various digital television proposals now under consideration or potentially available in the future, the change will have a massive economic impact upon US consumers. Moreover, depending upon where the replacement units are manufactured, the shift to digital television could have a material impact upon the US balance of trade. The aggregate cost of converting to digital television may well be without precedent for any government-mandated, but not government-funded, program. Consequently, this action — and all of the myriad of details attendant thereto — requires careful planning and analysis, extended technological forecasting, and a comprehensive and economically sound migration strategy.

Significantly, the move to digital television comes at a time of rapid — and accelerating — technological change in the consumer electronics and computer industries. For most of its 60 years, the present NTSC analog television standard has had to survive

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1. Consumer Electronics Information Service, *USA Market Forecast*, August, 1995. It is estimated that 98% of US households have at least one NTSC television set, and that 87% of US households have at least one NTSC-compatible VCR. Comments of the Electronic Industries Association in MM Docket No. 87-268, filed November 20, 1995, at 13.

2. *Id.*

what are, by current trends, only modest evolution. The original monochrome NTSC format was transformed through an orderly migration to a compatible color format; compatible multiplexed stereo sound was overlaid onto the audio channels, and picture quality was enhanced, and additional user features were introduced, *at the receiving end* through developments in high-end, digitally enhanced receivers. None of these changes required wholesale change-outs of the installed base or the creation of new broadcast channels. Whereas the personal computer has moved through at least five generations since its introduction less than twenty years ago, the 60-year-old NTSC standard is still lingering at a second generation level.

The two most common NTSC devices are the home television receiver and the home videocassette recorder.[3] Once consumers become aware of the impending elimination of NTSC broadcasts, they are likely to defer replacement of existing equipment or the purchase of new units until the new digital sets are available at price points that are comparable to those customarily associated with NTSC equipment. At the same time, consumers (other than the "early adopters") are unlikely to rush out and purchase new digital TV sets, VCRs, and other devices until (a) a sufficiently large number of broadcast hours are offered in the new format, and (b) the prices for the new equipment, or for equipment to adapt NTSC equipment to the new digital format(s), decrease to "affordable" levels.

Public acceptance of digital television will depend critically upon the manner in which the migration is managed. Merely being "better" does not by itself assure success, and any attempt to impose costs upon consumers without their perceiving a commensurate benefit could engender large-scale political resistance that could work to undermine - and perhaps even cripple — the Commission's efforts to establish the new format.[4]

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3. Other NTSC-format consumer products include VHS and 8 mm camcorders, laserdisc players, and video game devices that use the TV set as a graphic display screen. The installed base of these units are estimated at 23-million, 2-million and 44-million, respectively. Electronic Industries Association Research Center, January, 1996.

4. In 1984, the FCC undertook to effect a fundamental change in the structure of local and long distance telephone rates in the United States through the introduction of an end-user "Subscriber Line Charge" (SLC). *MTS/WATS Market Structure*, CC Docket No. 78-72, *Second Reconsideration Order of the Third Report and Order*, 97 FCC 2d 834 (1984). By imposing a small ($3.50 for residential customers, up to $6.00 for business lines) fixed monthly increase to the customer's monthly phone bill, the Commission was able to bring about large reductions in interstate long distance rates. Even though the residential SLC was phased in over a five-year period, and even though residential long distance rates have dropped by nearly 45% since the initiation of the FCC's "access charge" program, the agency was confronted with massive consumer resistance to the new charges, and as a result has been reticent to increase them above present levels *despite compelling economic evidence that such additional rate rebalancing would be efficient and in the public interest*.

Factors influencing the potential demand for and acceptance of the new digital formats

There are a number of factors that will operate to influence the demand for DTV devices. The two most obvious ones are *price* and *availability of programming*. These two factors are highly interdependent: Consumers will purchase DTV devices only when there is an adequate supply of programming, and broadcasters will offer such programming only when there is an adequate installed base of compatible receivers. Although price is a major factor, the consumer demand for DTV receivers and converters will be heavily influenced by "externalities" such as the aggregate penetration rate and the resulting availability of DTV programming. Demand externalities of this type are important in network-based industries, where the usefulness of the product to an individual consumer increases as the overall demand for the product grows. Several recent examples of this phenomenon can be cited. For example, a customer's willingness to purchase a fax machine is a function both of the price of the unit and the total population of fax machines with which it can communicate. Although fax technology had been on the market for several decades, significant growth did not occur until the price fell below the $1,000 level (for businesses) and the $500 level (for consumers), and the overall installed base of *compatible* machines had reached a "critical mass" such that users perceived substantial value of being accessible via fax.

At the outset, DTV converter and receiver prices are likely to be high (moreso under the ACATS proposal), and the availability of programming that is compatible with the new digital format(s) will be very limited. Thus, even if price points are eventually reduced to "affordable" levels, the initial roll-out will be slow, unless the initial price levels are attractive to more than the "early adopters." The availability of low-priced converters will foster a more rapid growth in overall penetration, which will in turn induce broadcasters and other program providers (e.g., cable TV, DTH satellite, videodisc) to make more programming available in the compatible digital formats. Increased availability of programming will stimulate additional consumer demand for DTV units at the same price points, leading in turn to increased manufacturing efficiencies and lower prices overall.

Although one can envision a scenario in which the roll-out of low-priced, low-end digital converters can take place over a relatively short span of years, at the outset at least, HDTV penetration is likely to be extremely small under any migration scenario. There are several reasons for this expectation:

- The relatively high price and physically large screen size required for HDTV will place it beyond the reach of most consumers

- With the exception of videophiles and early adopters, there is little market evidence that consumers are willing to pay large premiums for high-quality video. Indeed, existing high-quality NTSC products (high-resolution NTSC receivers, laserdisc players, Hi-8 camcorders, S-VHS VCRs) have extremely low penetration rates when compared with their low-end counterparts. Although these high-end NTSC products do not match the picture quality of HDTV, they also do not cost as much as the initially-projected prices of HDTV equipment. HDTV penetration rates, *a priori*, cannot be expected to be any higher than those associated with high-end NTSC products.

- Only a limited number of hours of HDTV broadcasting will likely be available during the first several years following its introduction.

- Consumers will be offered digital converters that will permit digital broadcasts to be viewed on conventional (analog NTSC) receivers, much as DTH digital satellite television converters perform this function today. These converters will cost a small fraction of the cost of an HDTV digital television receiver. However, assuming that the converter can process HDTV signals, the existing NTSC set with which it is associated will only be able to display HDTV signals in standard (low-definition) resolution.

In considering alternative DTV proposals, it is essential that the Commission give consideration to the potential each affords for the ultimate success of the migration to digital TV. For the reasons set forth below, there is strong reason to believe that the minimum baseline format proposal being advanced by CICATS is far more likely to result in a relatively rapid and successful migration than the more rigid ACATS plan.[5]

The ACATS proposal promises a slow and highly uncertain migration path.

Under the ACATS proposal, a total of four resolution levels — two standard definition and two high-definition - would be supported. In order for a consumer to be capable of receiving all digital TV broadcasts (which may be in any of these formats), the receiver or converter would have to support all four resolution levels. If a broadcast is transmitted at a definition level in excess of the capability of a particular receiver or converter, no video image will be displayed.

5. This paper is limited to comparing the ACATS proposal with the CICATS minimum baseline format proposal, and does not examine the economic issues associated with a voluntary standard approach.

Individual programs, however, will be broadcast in only one of the ACATS formats. Thus, in order for a standard-definition screen to display an HDTV broadcast, the receiver would have to receive and decompress the HDTV signal, convert it to a lower definition level, and then display the picture on the standard definition screen. Thus, while the ACATS proposal does not require that all consumers immediately purchase an HDTV receiver, it does effectively require that all digital TV receivers and converters be capable of decompressing and displaying the HDTV signal in whatever resolution the individual set supports.

According to cost estimates developed by CICATS,[6] even a converter *sans display screen* that is capable of receiving and decoding all ACATS formats will be costly to produce and will thus carry a relatively high price. CICATS has estimated that, using 1996 technology and cost levels, an ACATS converter would have to sell for $1.350.[7] This price level will decrease over time, as the cost and capabilities of digital electronics continue to improve. By 2007, the tenth year following the initiation the DTV broadcasts, an ACATS converter would cost consumers about $103. If the migration is moving according to plan, however, the acquisition of the converters will be occuring steadily over the period. Table 1 below assumes a penetration rate that starts out slowly but picks up the pace beginning in the fifth year. By the end of 2007, consumers will have been required to spend some $91-billion (in 1996 constant dollars) to convert existing analog NTSC sets to digital. This is, of course, an extremely conservative estimate, because it assumes that all consumers purchase converter units and that no integrated digital TV receivers are sold. It also assumes that the same converter is shared by the TV receiver and VCR. Note also that none of the costs that will be confronted by broadcasters for DTV production and transmission equipment are included in this estimate.

There is, however, an alternate migration scenario under the ACATS approach that would impose far lower costs on consumers, but would undermine fundamentally the Commission's efforts to introduce and establish HDTV. In this scenario, faced with the high cost of converters that are capable of decompressing HDTV signals (for display on low-resolution NTSC receivers), manufacturers would produce and offer "stripped down" converter boxes that are only capable of supporting the two standard definition ACATS resolution levels. CICATS has estimated that the 1996 cost of such units would be about $500,[8] or about 37% of the $1,350 cost for the fully-equipped device. Of course, con-

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6. See "Cost Comparison of ACATS and CICATS Set-top Converters, Receivers, and PC Decoders," Exhibit C to these Comments.

7. *Id.*

8. We assume for this example that the cost of a low-end ACATS converter is comparable to that for a base-line CICATS unit.

sumers who elect to purchase such stripped-down converters could not receive any HDTV broadcasts at all (i.e., their screens would be blank during such broadcasts), but that may not be perceived as being a particularly serious problem, especially if only a limited amount of HDTV programming is offered. In Table 2, we assume that 80% of consumers purchase the low-end (SDTV) units, and that only 20% purchase the more expensive HDTV-capable devices. By the end of the year 2007, consumers will have spent some $56-billion on digital converters, but only 20% of those devices will be capable of decoding HDTV signals.

Or course, this scenario creates a serious dilemma for broadcasters and other program producers. Not only are they confronted with additional costs to *produce* the HDTV program, but with the vast majority of converters being incapable of receiving such broadcasts even in low-resolution format, the broadcasts will reach a highly attenuated audience. Broadcasters and sponsors will, obviously, be reluctant to pursue HDTV if by so doing they would undermine their audience shares, and hence the proliferation of lower priced non-HDTV-capable converters will retard, if not arrest, the development of HDTV.

Adoption of the ACATS plan thus confronts the Commission with a Hobson's Choice:

(1) *It can mandate that all digital converters and receivers sold in the United States be capable of receiving all ACATS formats.* This, in turn, will result in high prices for the ACATS converters and receivers, resulting in substantial consumer resistance to the Commission's migration efforts and potentially resulting in an protracted extension of conventional NTSC broadcasting.

(2) *It can permit manufacturers to offer any subset of the four ACATS resolution levels.* If the Commission declines to establish receiver standards, the result may be faster acceptance of digital television, but could seriously undermine efforts to introduce and establish HDTV. This is because most consumers will not be willing to spend the additional amount to acquire an HDTV-capable converter or receiver, and broadcasters will be unwilling to offer programming that is capable of reaching only a small fraction of the population.

Choice (2) also runs the risk of creating substantial consumer uncertainty. While the differences among the various ACATS formats for each of the four levels of resolution may be of considerable interest to the engineers and manufactuers who have promoted their adoption, from the perspective of the average consumer the differences will be largely transparent and hence inconsequential. As such, it is unlikely that multiple standards for each resolution level will survive in the market.

Consider, for example, the case of videocassette formats. From the consumer's standpoint, the principal difference between the Beta and VHS formats was that they were

mutually incompatible. Once the installed base of VHS machines reached critical mass and easily dominated the installed base of Beta VCRs, prerecorded material ceased to be offered in the Beta format, causing demand for Beta machines to all but disappear. The dominance of VHS over Beta was not the result of any obvious technical superiority or expanded functionality, it was merely the result of market externalities that forced the market to adopt one standard. Indeed, it is extremely rare for multiple standards offering equivalent functionality to exist simultaneously, and old standards are replaced only when consumers view the new standard as being demonstrably superior.

Thus, if the ACATS plan is adopted, it is unlikely that all four resolution levels will survive; it is far more likely that at most two (one SDTV and one HDTV) will withstand the test of market acceptance. The problem, of course, is that we can't be certain as the outset as to which formats will win and which will lose.

The CICATS proposal offers a more efficient, market-driven migration plan.

The CICATS plan places responsibility for signal compatibility upon the *broadcaster* rather than on the home receiver or converter. The CICATS plan would require that all digital broadcasts include a standard definition digital signal that would be capable of being received by all DTV converters and receivers, permitting the broadcaster to use the remaining bandwidth for HDTV or other advanced services using data layering to create any of several possible voluntary formats. Because the basic SDTV signal would always be transmitted, a consumer with even the most bare-bones converter unit would always be able to receive the program. Under the CICATS proposal, full migration to digital television could be accomplished far more rapidly than under the less flexible ACATS plan:

- The cost of the basic converter unit would be considerably lower than for the full (all-format) ACATS unit.

- By adopting the PC-compatible progressive scan, 72-FPS scan rate, consumers with home PCs and PC monitors could benefit from the higher quality digital broadcasts without the need to purchase separate digital television receivers.

- Since all digital converters/receivers would be capable of decoding all digital programs (at least at the baseline level), broadcasters would be able to schedule HDTV programs without loss of audience.

- The lower cost of the converters, the acceleration of beneficial use of digital television through the use of PCs and PC monitors, and the incentives offered to

broadcasters to expand their digital and HDTV programming will result in a more rapid migration to digital TV, allowing for earlier discontinuation of NTSC broadcasts than under the ACATS formula.

The overall cost of the migration under the minimal standard approach being supported by CICATS would be considerably lower than that required for adoption of the ACATS plan with all ACATS converters having the full four-resolution-level capability. In the illustration presented in Table 3, total consumer cost for converters through the year 2007 would be about $47-billion (in constant 1996 dollars), or about half of the cost consumers would confront if they are required to purchase HDTV-capable ACATS converters. Moreover (but not specifically accounted for in Table 3), the accelerated rate of consumer acceptance will encourage more digital and HDTV programming, leading to increased demand for converters and correspondingly lower manufacturing cost and retail price levels.

The broadcasters' support for the ACATS plan may well be motivated by an agenda that is not consistent or compatible with the Commission's overall DTV goals.

Television broadcasters have generally (although not entirely) supported the ACATS plan for DTV. While they support the technical standard that ACATS has developed, the broadcasters oppose any mandatory requirement for a minimum number of HDTV broadcast hours.

While there can be little question as to the economic interest of the television set manufacturers in the adoption of the ACATS proposal, the interests and motivations of the existing TV broadcasters are far less clear and are, in any event, considerably more complex. How, precisely, will the over-the-air broadcast television stations actually benefit from digital television and, in particular, from HDTV? It is less than obvious, for example, that advertising rate levels under DTV would necessarily be any higher than those applicable today, since these rates are a function of the program content and audience size, and not *per se* the technical character of the image that is broadcast. Even if the over-the-air broadcasters could command higher unit advertising charges for digital (vs. NTSC) broadcasts (which is highly unlikely), the marginal gain would likely be more than offset by the increased amount of competition that would be present. Not only does digital television offer the prospect of additional TV channels within the VHF and UHF bands, the same digital converter boxes could also be used to receive digital satellite television and cable channels, further eroding the over-the-air broadcasters' market share and potential advertising revenues.

On the other hand, whereas the FCC and the TV set manufacturers would generally benefit from an accelerated migration to the new formats, such an outcome would be decidedly *contrary* to the over-the-air broadcasters' interests. Under the FCC's current plan, existing broadcasters will in the very near future likely be given the opportunity to apply for additional channels for digital broadcasts. They would retain their existing analog channel until the final cutover date, when all NTSC channels would be converted to DTV. Even if the FCC adopts a firm target date for the dismantling of all NTSC channels, as a practical matter this will not take place unless the digital converter/receiver penetration rate has reached a sufficiently high level. Until that occurs, and notwithstanding any nominal target date than the Commission may have established, the analog channels will remain on the air.

Indeed, the possibility that the digital channels will be allocated through an auction process serves only to strengthen the resolve of the current television broadcast stations to retain their analog frequencies for as long as possible. It is thus not surprising that the broadcasters would support the digital standard that assures the longest migration interval, one in which consumers will have little incentive to purchase converters at their high initial price levels, and one in which the potential development of HDTV is most uncertain. I do not disagree with the broadcasters' position that no specific minimum number of HDTV programming hours should be mandated, because the development of HDTV should be driven by free market choice and not by bureaucratic mandate. However, the broadcasters' position on this issue may well be driven as much by their lack of both interest in and optimism about HDTV (not to mention their reticence to commit the massive amount of capital that would be required to support HDTV broadcasting) than by their philosophical commitment to marketplace choices. If the ACATS proposal is adopted, but without requirements that all ACATS converters be capable of receiving HDTV signals and that any minimum quantity of HDTV programming be provided, voluntary adoption of *any* of the ACATS digital television formats will likely be slow in coming.[9] Under the scenario outlined here, such an outcome would not be inconsistent with the broadcast licensees' interests and objectives

9. CICATS does not propose that the Commission impose either of these requirements.

The CICATS proposal offers maximum technological and market flexibility while assuring a finite migration program at minimum cost to the nation.

While not guaranteeing consumer acceptance of digital television, the CICATS proposal overcomes most of the specific shortcomings of the ACATS plan.

- It offers consumers the opportunity to purchase, at relatively low cost, converters or adapters that will permit *all digital broadcasts* to be received on existing analog television receivers and home PCs.

- It permits broadcasters to offer HDTV programming without limiting audience share to those consumers who have purchased high-end digital equipment.

- It will encourage more rapid migration, thereby accelerating the rate of equipment price decreases and programming availability

- It will minimize the aggregate cost to the nation for the conversion to DTV.

- It offers greater opportunities for the participation of domestic computer and software firms in the development and manufacture of DTV devices.

- It will permit the existing analog TV channels to be reclaimed for reassignment to advanced television stations at the earliest possible date.

Table 1

TOTAL CONSUMER COST OF ATV CONVERSION
USING FULL HDTV-CAPABLE ACATS CONVERTERS

Year	Total TV set Installed base (end of year) (000)	NTSC Installed base (end of year) (000)	NTSC sets converted in year Pct.	Qty (000)	Unit cost of full-function ACATS converter	Ann cost of ACATS converters ($000)
1996	213,700	213,700	0%	0	$1,350	0
1997	223,000	223,000	0%	0	$977	0
1998	232,500	209,250	10%	23,250	$713	16,565,625
1999	242,000	196,875	10%	21,875	$526	11,501,450
2000	252,948	166,258	20%	41,565	$394	16,366,026
2001	264,390	142,161	20%	35,540	$300	10,675,922
2002	276,351	107,885	30%	46,236	$234	10,836,642
2003	288,852	72,232	40%	48,155	$188	9,038,370
2004	301,919	42,649	50%	42,649	$155	6,597,332
2005	315,578	22,523	60%	33,785	$131	4,437,520
2006	329,854	11,040	70%	25,759	$115	2,958,302
2007	344,775	0	100%	25,962	$103	2,678,556
				0		
	Cumulative Cost					91,655,744

Table 2

TOTAL CONSUMER COST OF ATV CONVERSION
USING 20% HDTV, 80% SDTV MIX OF ACATS CONVERTERS

Year	Total TV set Installed base (end of year) (000)	NTSC Installed base (end of year) (000)	NTSC sets converted in year Pct.	Qty (000)	Wtd. Avg. Unit cost of ACATS converter	Ann cost of ACATS converters ($000)
1996	213,700	213,700	0%	0	$670	0
1997	223,000	223,000	0%	0	$496	0
1998	232,500	209,250	10%	23,250	$373	8,660,625
1999	242,000	196,875	10%	21,875	$285	6,242,343
2000	252,948	166,258	20%	41,565	$224	9,300,059
2001	264,390	142,161	20%	35,540	$180	6,403,704
2002	276,351	107,885	30%	46,236	$149	6,906,553
2003	288,852	72,232	40%	48,155	$128	6,144,087
2004	301,919	42,649	50%	42,649	$112	4,784,732
2005	315,578	22,523	60%	33,785	$101	3,422,225
2006	329,854	11,040	70%	25,759	$94	2,410,915
2007	344,775	0	100%	25,962	$88	2,288,456
				0		
	Cumulative Cost					56,563,699

Table 3

TOTAL CONSUMER COST OF ATV CONVERSION
USING CICATS BASE-LINE CONVERTERS

Year	Total TV set Installed base (end of year) (000)	NTSC Installed base (end of year) (000)	NTSC sets converted in year Pct.	Qty (000)	Unit cost of CICATS base line converter	Ann cost of CICATS converters ($000)
1996	213,700	213,700	0%	0	$500	0
1997	223,000	223,000	0%	0	$376	0
1998	232,500	209,250	10%	23,250	$288	6,684,375
1999	242,000	196,875	10%	21,875	$225	4,927,567
2000	252,948	166,258	20%	41,565	$181	7,533,568
2001	264,390	142,161	20%	35,540	$150	5,335,649
2002	276,351	107,885	30%	46,236	$128	5,924,031
2003	288,852	72,232	40%	48,155	$113	5,420,516
2004	301,919	42,649	50%	42,649	$102	4,331,582
2005	315,578	22,523	60%	33,785	$94	3,168,401
2006	329,854	11,040	70%	25,759	$88	2,274,069
2007	344,775	0	100%	25,962	$84	2,190,931
				0		
	Cumulative Cost					47,790,688